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12 a. DISTRIBUTION / AVAILABILITY STATEMENT

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13. ABSTRACT (Maximum 200 words)

Active Shells (AS) and Reactive Shells (RS) are proposed to attenuate the undesirable wave propagation developed by various sources of external excitations. Emphasis will be placed here on excitations resulting from moving ballistic pressures that are developed during the firing of projectiles in gun barrels. The proposed shells are envisioned to be made of tubes that have passive or active sources of mechanical impedance mismatch which are placed along their longitudinal axes. These sources can be active inserts or reactive stiffeners that are tuned for optimal performance. The geometrical parameters and location of the active inserts or the reactive stiffeners will be optimally determined to maximize the attenuation of the waves as they propagate from one end of the shells to the other. Such attenuation results from the proper interaction between the incident, reflected and transmitted waves at the zones of impedance mismatch in a way similar to what happens in reactive mufflers of passengers cars.

The development and the optimization of the RS model and RS will be carried out and the performance of the optimal configurations will be tested at the University of Maryland. The performance of prototypes of the successful configurations will be evaluated at the firing range of the U. S. Army Benet Laboratory in Watervliet Arsenal.

14. SUBJECT TERMS
Active Shells, Reactive Shells, Wave Propagation in shells, Impedance mismatch

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SUBMITTED FOR PUBLICATION TO (applicable only if report is manuscript):
1. M. Ruzzene and A. Baz, "Response of Active Periodic Shells to a Moving Projectile Propelled by an Inertial Pressure Wave", J. of Intelligent Materials and Structures, 2002.
2. O. Aldraihem and A. Baz, "Dynamic Stability of Stepped Beams under Moving Loads", J. of Sound & Vibration, Vol. 250, No. 5, pp. 835-848, 2002.
3. O. Aldraihem and A. Baz, "Moving Loads-Induced Intability in Stepped Tubes", accepted in J. of Vibration & Control, 2002.
4. O. Thorp, M. Ruzzene and A. Baz, "Attenuation and Localization of Wave Propagation in Rods with Periodic Shunted Piezoelectric Patches", J. of Smart Materials & Structures, Vol. 10, pp. 979-989, 2001.
5. G, Solarolli, Z. Gu, M. Ruzzene, and A. Baz, "Wave Propagation in Periodic Stiffened Shells: Spectral Fininte Element Modeling and Experiments", Accepted in Journal of Vibration & Control, 2001.
6. M. Ruzzene and A. Baz, "Dynamic Stability of Periodic Shells with Moving Loads", Smart Structures & Integrated Systems, Vol. 4327, pp. 497-512, 2001.

Sincerely,

Dr. Amr M. Baz
Professor

REPORT DOCUMENTATION PAGE (SF298)

ACTIVE AND REACTIVE SHELLS

(Grant # DAAD19-99-1-0200 – 39126 – EG)

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RESEARCH OBJECTIVES

This study aims primarily at demonstrating the feasibility of utilizing a new class of Active and Reactive Shells (AS/RS) in impeding the propagation of waves as they travel from one end of the shells to the other. The proposed shells are made of tubes that have optimal passive or active sources of mechanical impedance mismatch in an attempt to control the wave propagation along the shells. Such passive/active control capabilities aim ultimately at enhancing the dynamics and the critical velocities of the new generation of high-speed guns.

APPROACH

The approach adopted to achieve the objectives of this study involves:

a. Development of a general purpose spectral finite element model to describe the propagation of waves in variable-impedance shells. The model will predict the response as influenced by the geometrical and physical parameters of the shell as well as the introduced active/passive sources of impedance mismatch.

b. Development of optimum design strategies that can be used in conjunction with the finite element model, developed in (a), to enable the selection of the optimal configuration of the active/passive inserts based on rational design procedures. In this task, several design objectives will be considered to ensure a balance between the attenuation of the vibrational waves and the weight/energy of the passive/active inserts.

c. Experimental evaluation of the effectiveness of the active/reactive shells in suppressing the transmission of vibrations generated by step and sinusoidal excitations of different frequencies.

d. Investigation of the effectiveness of the prototypes of the active/reactive shells in suppressing the vibration during firing tests at the firing range of Benet Laboratory.

e. Investigation of the merits and limitations of the active/reactive shells as compared to conventional plain shells.

SIGNIFICANCE

The proposed concepts have numerous potential military and commercial applications. In the military field, the active and reactive shells can be utilized in manufacturing stable guns with high firing speeds. In the commercial field, drive shafts of cars and helicopters can be configured as active or reactive struts. Space platforms, large robotic manipulators and massive cranes are also among the candidate applications.

MANUSCRIPTS

1. M. Ruzzene and A. Baz, "Response of Active Periodic Shells to a Moving Projectile Propelled by an Inertial Pressure Wave", J. of Intelligent Materials and Structures, 2002.
2. O. Aldraihem and A. Baz, "Dynamic Stability of Stepped Beams under Moving Loads", J. of Sound & Vibration, Vol. 250, No. 5, pp. 835-848, 2002.
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SCIENTIFIC PERSONNEL

1 Graduate Student

and 1 PI

SCIETIFIC PROGRESS & ACCOMPLISHMENTS

The following is a summary of the accomplishments to date:

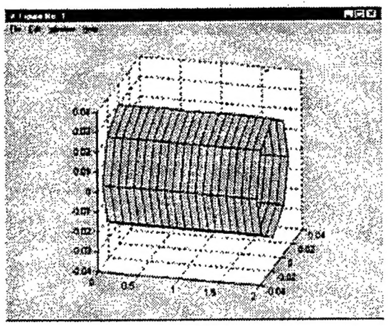
1. A finite element model is developed using 3-D elasticity equations of thin reactive shells.
2. A finite element model is developed using axi-symmetric thin reactive shells.
3. The time response of the radial and transverse deflections of shell are computed during the propagation of a pressure wave along the shell.
4. An experimental set up is under now construction to monitor the radial strains and the transverse deflection of different shell configurations due to the propagation of a pressure wave along the shell. The set up will be used to verify the predictions of the finite element models and monitor the elastic stability problems associated with high wave propagation speeds.
5. Development of dynamic stability boundaries of periodic gun barrels using wave propagation criteria.
6. Development of wavelet analysis strategies to determine the pass and stop band characteristics of gun barrels with periodic stiffeners.

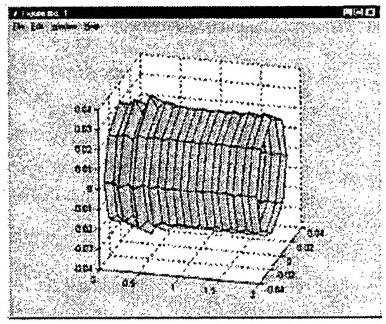
TECHNOLOGY TRANSFER

The developed concepts are now being considered to manufacture:

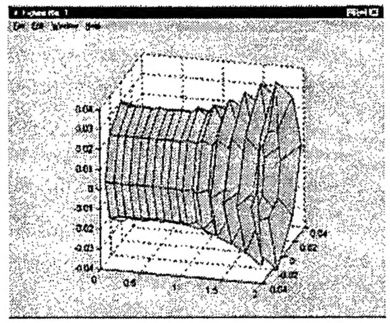
1. quiet torpedo shells with controlled wave propagation from the propeller to the torpedo nose where all the electronic sensors are located (ONR N000149910070).
2. Periodic struts for isolating the transmission of vibration of helicopter gearboxes to the airframe (Rotorcraft Center of Excellence at the University of Maryland).
3. Periodic driveshafts for isolating the transmission of vibration of tailrotor to the airframe (Rotorcraft Center of Excellence at the University of Maryland).

DYNAMIC RESPONSE OF PLAIN SHELLS TO PROPAGATION OF PRESSURE WAVES





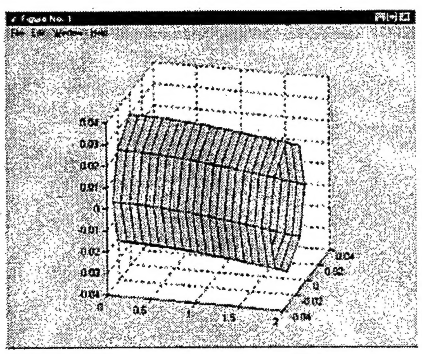
(a) –Start of wave propagation



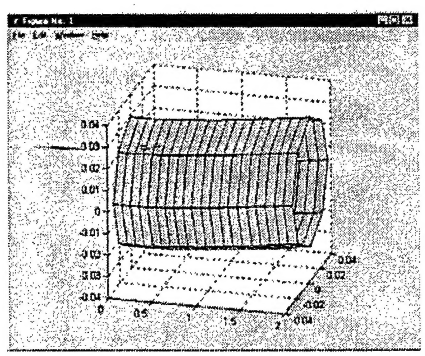
(b) – End of wave propagation

Undeformed Shell

Radial Deflection of shell



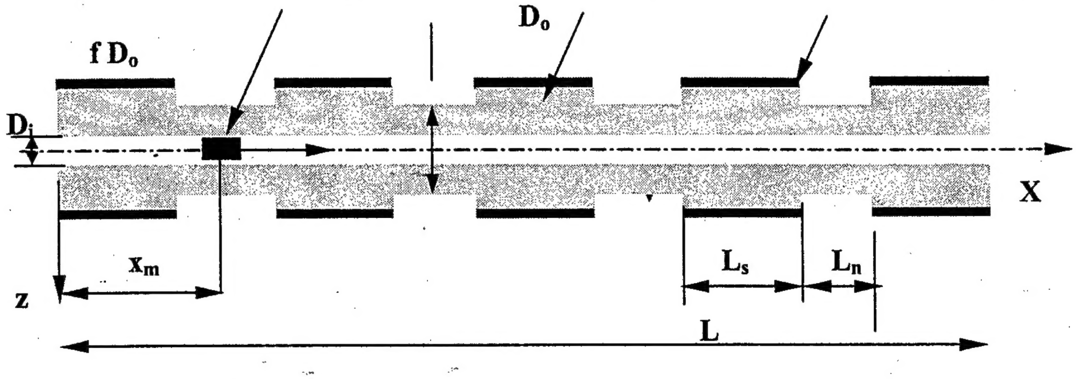
(a) – downward deflection



(b) – Upward deflection

Transverse Deflection Following the Release of the Pressure Wave Propagation

STABILITY OF ACTIVELY CONTROLLED STEPPED BARREL

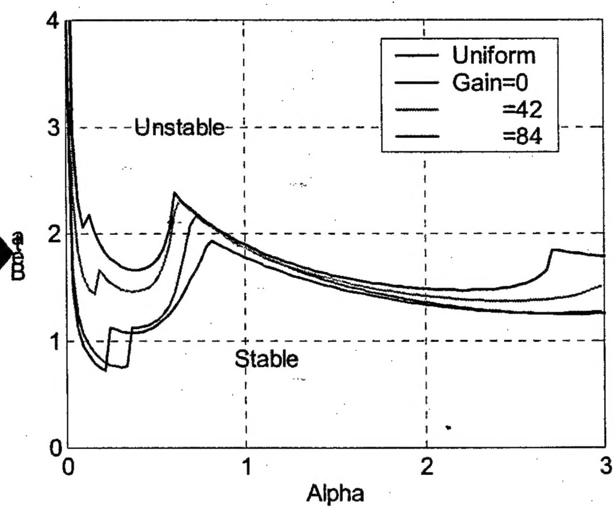


Stepped Active Barrel

Effect of Control gain on Stability Boundaries of Barrels

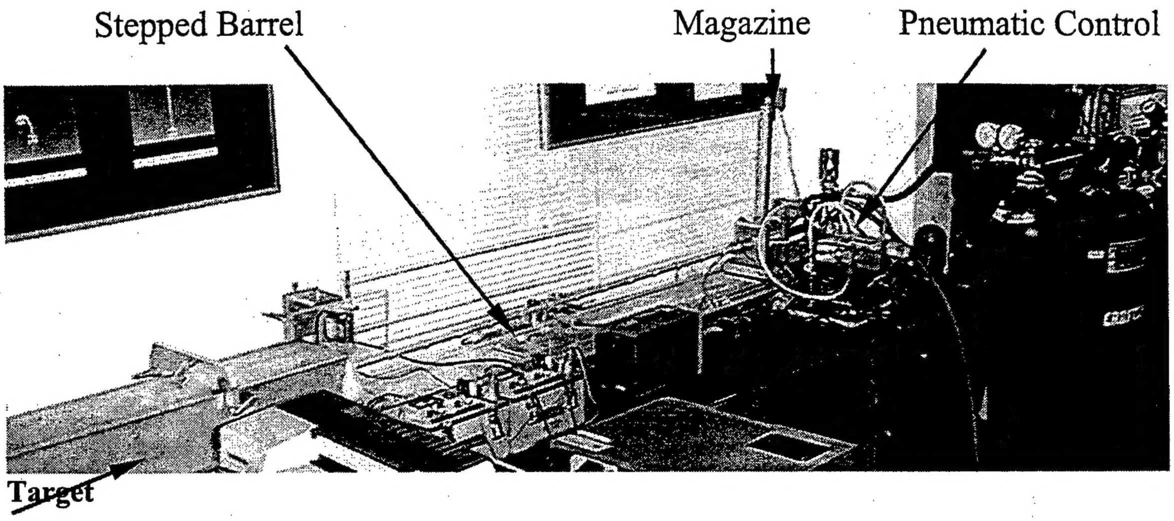
$$\text{Alpha} = \frac{m_v}{\rho AL} \text{ and Beta} = \frac{VL}{2\pi}\sqrt{\frac{\rho A}{EI}}$$

where V is the travel velocity

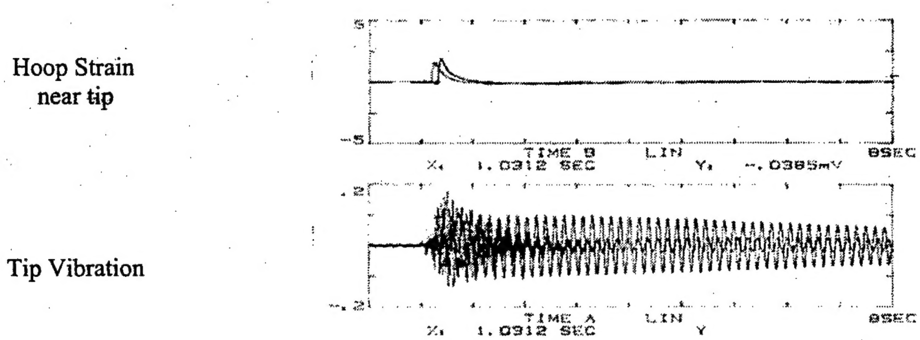


Increasing the control gain increases maximum travel Velocity (V) before t becomes elastically unstable particularl small travelling mass (m_v).

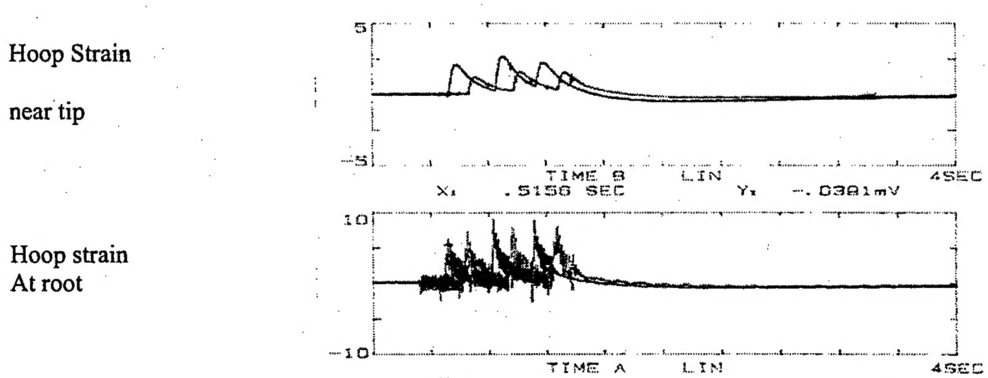
EXPERIMENTAL SET-UP OF ACTIVELY CONTROLLED STEPPED BARREL



EXPERIMENTAL RESULTS



Single Mass(Black – Plain Barrel, Red – Stepped Barrel)



Multiple Mass(Black – Plain Barrel, Red – Stepped Barrel)

STOP AND PASS BAND CHARACTERISTICS OF PERIODIC SHELLS